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journal or publication title	Journal of Developments in Sustainable Agriculture
volume	4
number	2
page range	141-148
year	2009
URL	http://hdl.handle.net/2241/113308

Journal of Developments in Sustainable Agriculture 4: 141–148 (2009)

Evaluation of Soil Fertility in the Sekhukhune District, South Africa

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This study investigated soil nutrients and organic matter and their effects on crop production at three sites in the Sekhukhune District of South Africa. Three study sites, Mporwane Project, Fetakgomo Project, and Ikageng Project were selected for the research. Sampling was collected from Ap horizon, at plough depth of 25 cm from the three sites The results showed that Fetakgomo project soils pH was higher than that of Ikageng and Mporwane was the lowest of the three sites, further more the pH was higher than required by the crops grown on the site. The electrical conductivity in Mporwane was the lowest of the three sites and Fetakgomo was the highest, the high electrical conductivity in Fetakgomo was a sign of high salt content in the soil which was sufficiently high to interfere with crops growth. Moisture in Fetakgomo and Ikageng soils was greater than Mporwane. Soils in Fetakgomo and Ikageng had high cation exchangeable capacity and exchangeable base than Mporwane. The high exchangeable bases and cation exchangeable capacity were considered to be attributed to clay content of the two sites, and to application of chemical fertilizers; while low soil chemical properties in Mporwane was due to the site soil structure and no application of organic and chemical fertilizers.

At the three sites there were different negative effects on crop production and attention was needed to changing farming systems to suit the soil. At Mporwane the soil nutrient contents needed to be improved. Fetakgomo and Ikageng projects had higher soil nutrients content than Mporwane; they also had high salt content, which was affecting plant growth. pH in both Fetakgomo and Ikageng project need to be reduced, proper farming techniques need to be applied to reduce soil salt levels at Fetakgomo and Ikageng projects. The appropriate salt-resistant seeds need to be used to suit the current condition.

Key words: soil chemical properties, chemical fertilizer, farming systems

Introduction

South Africa has a large agricultural sector and is a net exporter of farming products. There are almost a thousand agricultural cooperatives and agribusinesses throughout the country, and agricultural exports have constituted 8% of total South African exports for the past 5 years. The agricultural industry contributes around 10% of formal employment—lower than in other parts of Africa—and provides work for casual laborers, contributing around 2.6% of the nation's Gross Domestic Product. However, because of the aridity of the land, only 13.5% can be used for crop production, and only 3% is considered to have high potential (South Africa online, 2009). Crop yields are usually low because of poor soil fertility and rainfall patterns or poor availability of irrigation water.

There are still two distinct types of agricultural production system: large-scale commercial farming and smallholder farming. These two systems have evolved as a result of the policies of past governments under the apartheid regime. The outcomes of land reform and the acquisition of interests by black entrepreneurs in agribusiness will, over time, to cause the systems to merge.

Large-scale commercial farming systems that use the most advanced production technology occupy a

Received: October 1, 2009, Accepted: November 2, 2009

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larger total land area than the smallholder systems. These commercial farmers operate large farms that are well organized and situated on prime land. Farmers in this type of system cultivate vegetables throughout the year using chemical fertilizers, organic manure, and agro-chemicals. The majority of farmers individually purchase agricultural inputs such as fertilizers and chemicals from farm supply shops and cooperatives.

Farming under the smallholder systems is characterized by little production technology and small farm holdings of approximately 1.5 ha per farmer; production is primarily for subsistence and there is little marketable surplus (Limpopo Department of Agriculture, 2009). This dry-land farming is therefore aimed at self-consumption, with low inputs for cultivation of crops. Most farmers in these areas do not use any chemical fertilizer, organic manure, or agro-chemicals. Subsistence farmers cannot afford to purchase chemical fertilizers to supplement the soil, and this affects their production and plant growth, but commercial farmers are able to purchase chemicals to supplement their soils and increase production. Others, such those who run community gardens, buy inputs in groups of 5 to 10 members to bargain for better prices and transport costs. Most of the grain and bean seeds are self-supplied by cultivators from those left over from the previous season, but seeds of improved cultivars are used by some farmers. Most vegetable seeds are procured from farm supply shops in towns.

These are some of the problems with the farming systems and agricultural practices, including fertilization and irrigation, in South Africa. For good crop growth, we have to evaluate the soil conditions at a site by analyzing the soil chemical properties under conditions where soil amendment and irrigation are conducted and where no soil inputs are applied.

The objective of this study was to investigate the effects of soil nutrient concentration on crop growth at three sites in the Sekhukhune District of South Africa as a measure of soil fertility and to make recommendations for soil management at each site.

Study Sites

Three study sites were selected in the Sekhukhune District in the southern part of Limpopo Province: site 1 (Mporwane Project), site 2 (Fetakgomo Project), and site 3 (Ikageng Project) (Fig. 1). Sekhukhune District is one of five districts in Limpopo Province, South Africa. It is positioned at lat 29° to 30° and long 29° to 31°. Land-based agricultural production is the only opportunity available for poor rural communities. Most house-

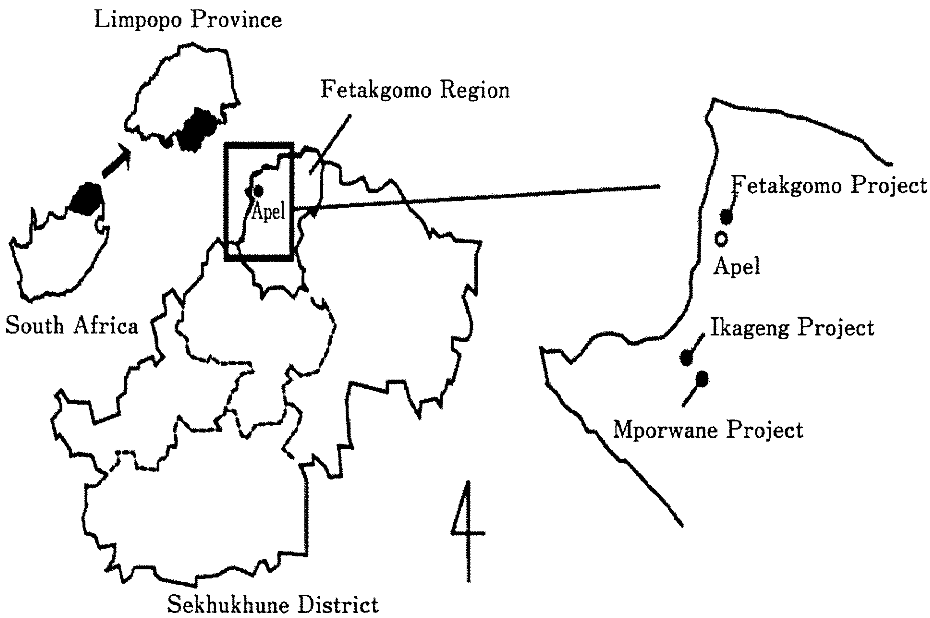

Fig. 1. Map of the Sekhukhune District in Limpopo Province.

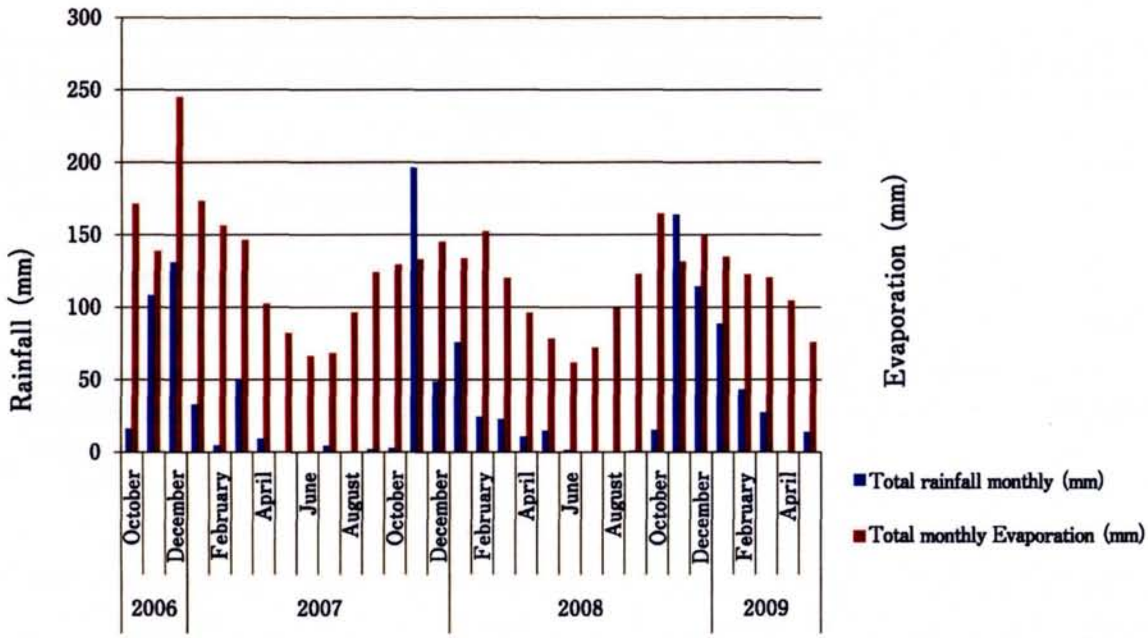

Fig. 2. Rainfall data for the study area.

holds in the district practice agriculture for self-sustenance. Some places have infrastructure such as irrigation, and on the larger land parcels commercial farming is practiced.

The climate in this region is characterized by droughts followed by heavy rainfall. Rain falls mostly in summer (October to March), with intensity ranging from 400 to 700 mm annually. Rainfall at the study sites is the lowest in the district, and evaporation rates are very high (Fig. 2). Most of the soil moisture is lost because of high evaporation and low rainfall during the rainy season.

The qualities and quantities of ground water differ from site to site in the area. The maximum flow rate of groundwater is around 2 to 5 L s^{-1} (Hiroaki Yonesaka and JICA Study Team, March 2007). Because of the low rainfall in the area little water penetrates to contribute to the underground water, so the use of groundwater in agriculture has been minimal. The alluvial sands of the Mohlaletsi and Lepellane Rivers and secondary aquifers in fractured and weathered rock are possible water sources. However, 40% of existing boreholes have high salt content (Hiroaki Yonesaka and JICA Study Team, March 2007).

The agricultural information on each site is given in Table 1. The seasonal cropping pattern in the Fetakgomo municipality, located in the northern part of the Sekhukhune District, was extensive sorghum cultivation as a dry-land crop, and millet, watermelon, cowpeas and maize as supplements during the rainy season. Some of the farmers cultivate fruit trees, including marula peaches, and cacti. Some farmers cultivate vegetables such as beetroot, butternut, tomato, onion, and spinach all year.

The population pressure in the municipality is high and has resulted in a reduction in the area of agricultural land. Most households have land titles in the range of 0.1 to 2 ha; the average area cultivated per household is around 0.33 ha. Medium-sized blocks of about 3 ha are usually owned by relatives of tribal leaders and other prominent members of the community.

Site 1 is land owned by the local chief; all the community members are given a portion of land to use to produce their crops; the land is allocated by the chief. Site 2 is owned by a group of people, each of whom has a small portion that is combined to form the total land area. Site 3 is also owned by a group of people with equal shares of the resource; the land ownership is the prerequisite for membership of the group.

Table 1. Profiles of the study sites

Input/item		Mporwane (site 1)	Fetakgomo (site 2)	Ikageng (site 3)
Land size		400 ha	10 ha	10 ha
Commodity		Sorghum, cowpea, watermelon, and maize	Vegetables (spinach, tomato, butternut) and poultry	Vegetables (spinach, tomato, butternut, onion, beetroot, watermelon, potato)
Irrigation		Rain-fed	Borehole	Canal
Soil amendments	Chemical	None	Ammonium nitrate (50 kg/0.5 ha)	Ammonium sulfate (50 kg/0.5 ha) Superphosphate (50 kg/0.5 ha)
	Organic	None	None	None
Soil type		Sandy	Clay loam	Sandy clay loam
Land ownership		Community	Group	Group

Materials and Methods

Sample Collection

Fetakgomo, Ikageng, and Mporwane were sampled separately. Samples were taken with a shovel to plow depth (0 to 25 cm). Samples were collected from 16 points in a field and mixed together; a composite sample of 650 g was thus collected from each site as representative of the soil at the site. These samples were air dried, the organic material was removed by pincette, and the soil was sieved with 2-mm sieve and portion of the sample passed through 2-mm sieved through 5-mm sieve for chemical analysis.

Chemical Analyses

Samples were subjected to the following chemical analyses (Committee of Soil Environment Analysis, 1997). Soil sample pH values were measured in a 1: 2.5 mixture of air-dried soil in distilled water and a 1 mol L^{-1} KCl mixture using a glass electrode pH meter. Electric conductivity (EC) was determined for a 1: 5 air-dried soil in distilled water mixture using a platinum electrode. Organic carbon and total nitrogen contents were determined by the dry combustion method with a Sumigraph NC-900 NC analyzer (Sumika Chemical Analysis Service, Tokyo, Japan). To remove inorganic carbon, samples containing carbonate (Fetakgomo and Ikageng) (Table 2) were treated with 1 N H_3PO_4 and dried. After drying, samples were analyzed as mentioned above. The calcium carbonate contents were determined by an acid neutralization method (International Soil Reference and Information Center, 2002). Exchangeable bases of Ca, Na, K, and Mg were extracted with 1 mol L^{-1} CH_3COONH_4 (pH 7.0) three times and quantified by using inductively coupled plasma mass spectrometry (Optima 4300 V; PerkinElmer, Waltham MA). Extractions were conducted with a soil to solution ratio of 1: 5. To measure cation exchange capacity (CEC), the residues after exchangeable base extraction were washed with water and 80% ethanol. Then, NH^{4+} was extracted three times with 1 mol L^{-1} NaCl (pH 7.0) with a soil-to-solution ratio of 1: 6, and quantified by a steam distillation method. Available phosphorus contents were determined by the molybdate blue Truog method (Committee of Soil Environment Analysis, 1997).

Results and Discussion

Soil pH (H_2O) at plow depth (25 cm) at the three sites varied (Table 2). Fetakgomo was moderately alkaline, Ikageng was slightly alkaline, and Mporwane was slightly acidic. The EC at site 2 was the highest among the three sites. The underground irrigation water used at site 2 was salty; this

Table 2. Chemical properties of soils at the study sites

Site name/items		Units	Mporwane	Fetakgomo	Ikageng
Horizon			Ap	Ap	Ap
Depth		(cm)	0-25	0-25	0-25
pH		(H_2O)	6.43	8.26	7.92
		(KCl)	4.71	7.78	6.46
EC (electrical conductivity)		(dS cm^{-1})	0.012	1.545	0.079
Water content		(%)	0.98	4.42	3.58
Organic carbon		(g kg^{-1})	1.45	5.28	4.74
Total nitrogen			0.17	0.63	0.63
C/N			8.55	8.44	7.51
$CaCO_3$		(%)	0.17	10.77	1.08
Available phosphorus		$mgP_2O_2kg^{-1}$	36.64	362.78	91.32
Exchangeable Bases	Na	($cmol_c$ kg^{-1})	0.00075	3.7	0.25
	K		0.1	1.21	0.76
	Ca		2.19	36.46	12.25
	Mg		1.81	26.01	10.6
Ca: Mg ratio			1.21	1.402	1.156
Cation Exchange Capacity		($cmol_c$ kg^{-1})	3.41	19.28	15.66
Base saturation		(%)	120.16	349.63	152.38

increased the salt content of the plow layer, which increased the pH. The soil at Fetakgomo contained carbonates, which contributed to the moderately alkaline soil pH. The presence of carbonates at the site was due to the supply of ammonium as ammonium nitrate to improve the soil (Table 1); soil ammonium levels are closely correlated with calcium carbonate content (Hesse, 1971). Saline soils with pH less than 8.5 have a detrimental effect on plants, largely because of their high soluble salt concentration: when water containing large amounts of dissolved salts comes into contact with the plant cells it causes shrinkage of the protoplasmic lining (Brady, 1979). Water does not evaporate as readily from the surfaces of saline soils as from non-saline soils; consequently, the salt solution can move toward the surface over long periods, thus increasing the number of surface salt patches (Hesse, 1971). The presence of salts in soluble form interferes with seed germination, plant growth, and plant uptake of water (Patiram *et al.,* 2007). Site 1 had low carbonate activity and its pH was lower than that of the two other sites. Calcium carbonates are not usually found in soils with pH less than 7 (Hesse, 1971).

The EC at site 2 was higher than that of site 3; site 1 had the lowest EC. The EC at site 2 and site 3 (Table 2) indicated that the soluble salt concentration was high enough to seriously interfere with plant growth (Brady, 1974). The EC at sites 1 was sufficiently low to be disregarded (Hesse, 1971) because they fell in the range from 0 to 0.02 dS cm^{-1} (Table 3), the salt content was enough to grow all crops grown in site 1 and would not have effect on the crops growth. However, the high EC at site 2 would have had an impact on plants that were sensitive to salinity, because at 1.545 dS cm^{-1} it fell into the range $>$0.16 dS cm^{-1}, at which only very salt-tolerant crops yield satisfactorily (Table 3). The excessive salt content in site 2 needs to be lowered; another alternative is to plant salt tolerate varieties to improve the productivity of the soil of the two sites. Site 3 EC was higher than that of site 1 and many crops affected at that range (Table 3). Soluble salts affect plants uptake of phosphorus, sodium, potassium, and especially calcium.

Table 3. Soil conductivity limits

Conductivity (dS cm^{-1})	
0–0.02	Salinity effects negligible
0.02–0.04	Very sensitive crops affected
0.04–0.08	Many crops affected
0.08–0.16	Yields of only salt-tolerant crops satisfactory
>0.16	Yields of only very salt-tolerant crops satisfactory

Source: Patiram, *et al.,* 2007.

The phosphorus content at site 2 was higher than that at site 3; the content at site 1 was the lowest. The pH at site 1 was relatively good compared with site 2 and site 3 for phosphorus availability: at pH 6 to 7, phosphorus fixation is at a minimum and phosphorus availability is at a maximum; in this pH range plants do not absorb half, or even one-third, of the available phosphorus, but crops can still benefit (Brady, 1974). Plants produced at the three sites prefer a pH that is slightly to moderately acidic, with the exception of potato and watermelon (site 3; Table 1), which prefers strongly acidic soils (Table 5). The high phosphorus content in site 3 was due to application of superphosphate (Table 1) and to make it available at its maximum, pH should be in range of 6–7 because of its maximum availability at pH range of 6–7 (Brady, 1974).

The organic carbon (OC) content at site 2 was higher than that at site 3; site 1 had the lowest OC. The low OC content at site 1 showed that the soil had a very poor physical structure, as evidenced also by the low water content (indicating low water-holding capacity) and low EC and CEC. Carbon levels at sites 2 and 3 were higher; this was a reflection of the better soil physical structure and EC and CEC values.

Levels of exchangeable bases were higher at site 2 than at site 3; site 1 had the lowest levels (Table 2). Site 2 had high content of Na, K, Ca, Mg than site 3, site 1 was the lowest of the three (Table 2). The high Na, K, Ca, Mg content in site 2 and site 3 was influenced by the soil structure of the two sites. Clay loam soil in site 2 and sandy clay loam in site 3 was liable in the adsorption of Na, K, Ca and Mg (Table 2). Clay particles, merely because of their fineness of division, expose large amount of external surface, which can increase adsorption of exchangeable cations because of their larger surface area (Brady, 1979). Site 1 exchangeable cation (Na, K, Ca and Mg) was the lowest of the three sites and this was also because of sandy soils (Table 1), which had low bases adsorption (Brady, 1979).

Nitrogen levels at sites 2 and 3 were the same and higher than at site 1. High nitrogen content in Site 2 was due to the application of ammonium nitrate. Site 3 also had higher nitrogen content which was because of application of ammonium sulfate, which contained nitrogen (Table 1). Site 1 had the lowest nitrogen content because it received no soil amendments (Table 1).

CEC at sites 2 and 3 was higher than at site 1. CEC at sites 2 and 3 was influenced by the soil properties: the clay content (Table 1) at the two sites contributed to the increased CEC and the sandy soil at site 1 contributed to the low CEC. The other contributing factor at sites 2 and 3 was the addition of chemical fertilizers; at site 1 no chemical fertilizer or organic matter was applied to improve the soil. CEC is the capacity of the soil to hold and exchange cations; it provides a buffering effect to change pH, nutrient availability, calcium level, and structure. The reason for the low CEC (Table 2) at site 1 was because of sandy soil of the site (Table 1): the sand structure of the soil influences the cation adsorption capacity because of sandy soil having low surface area (Table 1), sandy soil has high nutrient infiltration and leaching rates. Sites 2 and 3 had moderate CECs and site 1 had a very low CEC (Table 4).

The base saturation of site 2 was higher than that of sites 1 and 3. Sites 1, 2, and 3 were all rated as having very high base saturations (Table 4).

The Ca: Mg ratio at all the three sites was within the range of 1.156 to 1.402 (Table 2); site 2 had the highest ratio and site 1 had the lowest. All three sites Ca: Mg ratio was within the range of 1–4

(Table 4). The three sites are described as low in calcium content.

Conclusion and Recommendations

The soils at the three sites had different soil nutrient capacities. Different approaches to the three sites need to be developed to improve the soil condition. The pH at Mporwane (slightly acidic) was the best for growing many types of plants (Table 5). The However, the low readily available nutrient contents at this site caused production losses. Soil nutrients are depleted by plant growth and these results in depletion of soil fertility. The nutrients lacking in the soil could be replaced by the application of organic matter, organic manure, and nitrogen-fixing plants; this would also introduce carbon and nitrogen and improve the soil physical structure and soil moisture retention. Due to lack of funds to purchase inputs, use of organic material could beneficial to increase soil capacity and increase exchangeable bases.

The pH at Ikageng was higher than that required by many of the types of plants grown (Table 5). The salt content of the Ikageng soil was very regarded as high due to electrical conductivity being ranged $>0.16\,dS\,cm^{-1}$ (Tables 3). Salt content in the area was very high and only salt tolerant crops should be grown in the area. The Ca: Mg ratio revealed that Ca content was lower and it would not be advisable to improve Ca content to a balance (Tables 4). The pH would need to be reduced to suit most of the crops produced in the area and alternatively the farmers could use crops that are salt tolerant. Potato growing would need more attention, as the high pH may be causing reduced production. Soil pH is usually reduced by the use of acidifying agents such as elemental sulfur or sulfuric acid. When sulfur is added to the soil it combines with water and oxygen through bacterial activity and changes to sulfuric acid. The use of ammonium sulfate as a fertilizer will, however, reduce the pH of the soil immediately around the root (the rhizosphere) owing to the release of H^+ from the root system in ammonium; the $NH^+{}_4$ form of nitrogen is taken in by the roots (Swift, 2008). The soil at site 2 had high levels of salt, which would have led to loss of production, suitable crops that are salt tolerant crops can be beneficial and crop loss would be reduced.

Fetakgomo farmers need to adjust their farming

Table 4. Soil chemical parameters

Cation exchange capacity	
Rating	CEC ($cmol_c\,kg^{-1}$)
Very low	<6
Low	6-12
Moderate	12-25
High	25.0-40
Very High	>40
Ca: Mg ratio	Description
<1	Ca deficient
1-4	Ca low
4-6	Balanced
6-10	Mg low
>10	Mg deficient
Range (% base saturation)	Rating
0-20	very low
20-40	low
40-60	moderate
60-80	high
>80	very high

Source: Hazelton and Murphy, 2007.

Table 5. pH requirements of plants

Crop/vegetable	pH range
Spinach, beetroot	Slightly acidic to neutral
Watermelon, Potato	Strongly acidic
Onion	slightly acidic
Carrots, tomato, maize, cowpeas	Medium acidic to neutral
Cucumber	Slightly acidic to medium acidic

Source: Hazelton and Murphy, 2007.

system to suit the natural resources available to them. Salt content in the area limits and reduces crop growth, high salt tolerant seeds crops would be advisable to sustain crop growth and maintain productivity. The high pH in the area needs to be adjusted to suit the crops grown; the current pH is above the required by the crops. Acidifying agent should be applied to reduce pH to the required level by vegetables in the area. Ca: Mg ratio of Fetakgomo soils result is 1.402 which is ranged 1–4 category and this meaning low Ca content in the soil. Application of chemical fertilizer (ammonium nitrate) should be well timed to reduce loss. Ammonium nitrate is converted by biological activities into available nitrogen and the loss may occur over long periods when soil is not planted.

Acknowledgements

I would like to thank Professor Teruo Higashi, Graduate School of Life and Environmental Sciences, University of Tsukuba for his guidance and assistance in my analysis of samples in the laboratory. I also thank Dr. Kenji Tamura, Graduate School of Life and Environmental Sciences, University of Tsukuba, for his guidance and encouragement throughout my study at the University of Tsukuba. I also appreciate the help of Takashi Kanda, Shokichi Wakabayashi, Shoko Suzuki and the students of the Laboratory of Environmental Soil Chemistry, Graduate School of Life and Environmental Sciences, University of Tsukuba.

Thanks also to Japanese International Cooperation Agency and staff, especially Ms Nakano Makiko, Ms Akiyama Sachiyo, and Mr. Aizawa Eishi, for their support during my stay in Japan. I also thank them for giving me the chance to improve my knowledge and skills in order to help my country.

Lastly, I want to thank my General Manager Mr. J. Nowatha, and Mr. P. Mashiane and the staff of the Limpopo Department of Agriculture, for giving me the time and support to study in Japan. I appreciate the support of my colleague Mr. Nthlane Lesetja and of my family for sending samples and data to me in Japan.

References

Auset T *et al.*, Methods for Soil Environment Analysis, 1997. Committee of Soil Environment Analysis publisher, Tokyo, 427 pp.

Brady, N.C., 1974. The Nature and Properties of Soils, 8th Edition, Macmillan Publishing. Co. INC, London, 639 pp.

Hazelton, P.A. and Murphy, B., 2007. Interpreting Soil Test Results, What Do All The Numbers Mean?, Commonwealth Scientific and Industrial Research Organization Publishing (CSIRO), 152 pp.

Hesse, P.R., 1971. A Textbook of Soil Chemical Analysis, J Murray publisher, London, 520 pp.

Hiroaki Yonesaka and JICA Study Team, March 2007, Study on the Integrated Holistic Rural Development and Soil Conservation Programme in the Schoonoord Area in Sekhukhune District, IC Net Limited Taiyo Consultants CO. LTD, Tokyo, 345 pp.

Limpopo Department of Agriculture, 2009. http://www.lda.gov.za/

Patiram, B., Azad Thakur, N.S. and Ramesh, T., 2007. Soil Testing and Analysis: Plant, Water and Pesticide Residues. New India Publishing Agency, New Delhi, 220 pp.

Reeuwijk L.P., Procedure for Soil Analysis, Sixth Edition, 2002. International Soil Reference and Information Center publisher, The Netherlands, 101 pp.

South Africa online, 2009, http://www.southafrica.co.za/agriculture_29.html

Swift, C.E., 2008. Alkaline Soils and the Buffering Affect [sic] of Calcium Carbonate. Colorado State University Extension. http://www.coopext.colostate.edu/TRA/PLANTS/index.html#http://www.coopext.colostate.edu/TRA/PLANTS/alksoil.html